

## Clue Insensitivity in Remote Associates Test Problem Solving

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### Abstract:

Does spreading activation from incidentally encountered hints cause incubation effects? We used Remote Associates Test (RAT) problems to examine effects of incidental clues on impasse resolution. When solution words were seen incidentally 3-sec before initially unsolved problems were retested, more problems were resolved (Experiment 1). When strong semantic associates of solutions were used as incidental clues, however, it did not improve resolution (Experiments 2 and 4). The semantic associates we used as incidental clues primed our RAT solution words in a lexical decision task, but they did not facilitate impasse resolution unless participants were explicitly instructed to use the associates as hints to the retested problems (Experiment 4). The results do not support the theory that spreading activation is a sufficient cause of incubation effects, and suggest that serendipitously encountered clues (i.e., words that are semantically related to RAT solutions) have no automatic benefit on impasse resolution in RAT problem solving.

### Keywords:

remote, associates, incubation, hint

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## Introduction

### ***Remote Associates Test Problems and Studies of Creative Cognition***

Experimental studies of cognitive mechanisms involved in creative thinking have engaged a number of different laboratory tasks, such as insight problems (e.g., Dominowski & Jenrick, 1972; Metcalfe, 1986), divergent thinking tasks (e.g., Diehl & Stroebe, 1991; Kohn & Smith, 2010), and idea generation tasks (e.g., Smith, Ward, & Schumacher, 1993; Ward, 1994). Remote Associates Test (RAT) problems, which were utilized in the present experiments, afford a natural link between a long tradition of verbal learning paradigms, such as paired associates learning, with the cognitive processes involved in creative thinking, such as retrieving remotely associated ideas. In both cases, the focus is upon associative processes among verbal stimuli, the focus of interest in the present study and others (e.g., Haarmann, George, Smaliy, & Dien, 2012; Storm & Koppel, 2012). Because solutions to RAT problems are susceptible to competitive interference effects, it has been possible to block or interfere with RAT problem solving performance by priming inappropriate (nonsolution) associates, resulting in fixation effects (e.g., Dodds, Smith, & Ward, 2002; Kohn & Smith, 2009; Smith & Blankenship, 1991; Vul & Pashler, 2007). In the present set of experiments, we again took advantage of the verbal and associative nature of the RAT problems to examine the effects of hints in the form of *semantic associates of solution words* on impasse resolution in RAT problem solving; does spreading activation from such hints cause incubation effects?

### ***Incubation and Sub-threshold Activation***

RAT problem solutions that are inaccessible during initial problem solving attempts might become accessible following a period in which work on the problem has been put aside temporarily, a period known as an *incubation interval*. The resolution of initially unsolved problems on a retest is referred to as an *incubation effect*. Several theories have been proposed to explain the mechanisms responsible for incubation effects. According to the forgetting fixation hypothesis, the period during which a problem is set aside allows incorrect answers to diminish in accessibility, thus making solutions more accessible during later attempts (Smith & Blankenship, 1989). Smith and Blankenship demonstrated increased forgetting for incorrect answers to problems following longer incubation periods. Supporting the forgetting fixation hypothesis, the proportion of forgetting for incorrect answers was associated with successful problem solving during a second attempt for problems that were initially unsolved.

An alternative explanation for incubation effects predicts that when a problem is set aside, relevant information in the environment may trigger retrieval of once-inaccessible solutions. Yaniv and Meyer (1987) proposed that spreading activation facilitates solution accessibility during an incubation period. "If both the partial access of key items' mem-

ory traces and the progression of inferences through other relevant stored information generate some spreading activation, then subsequent enhanced memory performance ultimately could yield successful solutions (Yaniv & Meyer, 1987, p 189).” The activation imparted to once-inaccessible solutions occurs by the passive and automatic process of spreading activation, the same process used to explain semantic priming effects found with a lexical decision task (e.g., Meyer & Schvaneveldt, 1971). To observe this putative sub-threshold activation, Yaniv and Meyer measured reaction times in a lexical decision task for target words that participants previously had failed to retrieve (cued by definitions of target words). They found faster reaction times for targets of initially failed retrieval attempts, particularly for items associated with stronger feelings-of-knowing judgments, which Yaniv and Meyer took as evidence of sub-threshold activation. Thus, this spreading activation theory of incubation effects maintains that initial attempts cause sub-threshold activation of target solutions, and spreading activation from related stimuli that are incidentally encountered adds enough activation to make solutions more accessible on a subsequent attempt. For an alternative explanation of Yaniv and Meyer’s results, however, see Connor, Balota and Neely (1992).

Other methods have been used to examine sub-threshold activation that supposedly occurs outside of consciousness. Bowers, Regehr, Balthazard and Parker (1990) measured what they referred to as intuitive guiding, the perception of a pattern or schema (referred to as coherence) that guides hunches during problem solving, which might lead a problem solver towards correct solutions. Perception of coherence is supposedly based on unconscious activation that accrues at semantic representations of solutions. “By a process of spreading activation (Collins & Loftus, 1975) clues that reflect and ultimately reveal coherence automatically activate relevant mnemonic networks – thereby producing a tacit or implicit representation of coherence (Bowers et al., p.74).” Bowers et al. used RAT problems, based on the theory that activation spreads from each word of a RAT triad to that word’s associates (see Figure 1).

The solution to a coherent triad, therefore, gets activation from each of the three problem words, and the activation from each stimulus word adds incrementally to the activation of the solution, even if that level of activation does not exceed a threshold for conscious awareness (upper panel of Figure 1). Thus, Bowers et al.’s theory predicts that activation spreads without awareness from any encountered stimuli to solutions via passive spreading activation. In support of this theory, Bowers et al. found that participants, when presented with a pair of RAT problems—one of which had a solution (the coherent triad) and the other triad did not have a solution—were able to guess which was the solvable RAT problem at greater than chance levels, even when participants were unable to consciously access the problem’s solution, an intuitive guiding effect. This effect was stronger in cases in which confidence was stronger. Bowers et al. attributed the success of this intuitive guiding effect to unconscious activation of solution words.

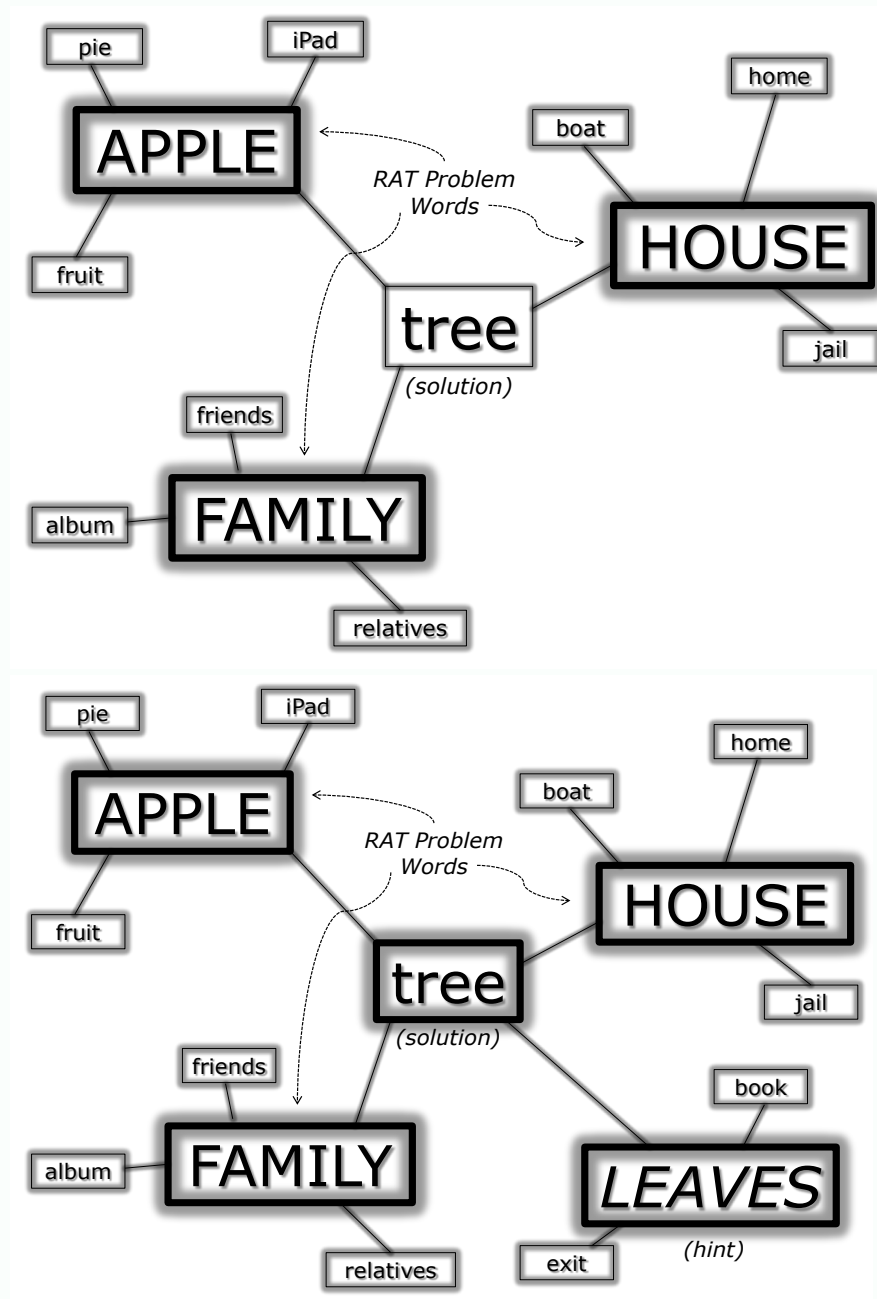


Figure 1. In the top panel, activation spreads from three RAT problem words to the solution word, such that the solution (*tree*) accumulates more activation than other associates. In the bottom panel, extra activation spreads from a hint, a close associate to the solution word (*leaves*), making retrieval of the solution easier.

The solution to a coherent triad, therefore, gets activation from each of the three problem words, and the activation from each stimulus word adds incrementally to the

activation of the solution, even if that level of activation does not exceed a threshold for conscious awareness (upper panel of Figure 1). Thus, Bowers et al.'s theory predicts that activation spreads without awareness from any encountered stimuli to solutions via passive spreading activation. In support of this theory, Bowers et al. found that participants, when presented with a pair of RAT problems—one of which had a solution (the coherent triad) and the other triad did not have a solution—were able to guess which was the solvable RAT problem at greater than chance levels, even when participants were unable to consciously access the problem's solution, an intuitive guiding effect. This effect was stronger in cases in which confidence was stronger. Bowers et al. attributed the success of this intuitive guiding effect to unconscious activation of solution words.

The work of Yaniv and Meyer (1987) and Bowers et al. (1990; 1995) is consistent with the idea that activation spreads passively from incidentally encountered stimuli to semantic associates of those stimuli (see also Collier & Beeman, 2012). Yaniv and Meyer's (1987) theory predicts that simply reading a hint that is semantically related to a RAT solution word should increase the likelihood of accessing that solution. This situation is depicted in the lower panel of Figure 1, in which a RAT solution word receives activation from the three problem words, and additional activation from a fourth word. This fourth word, an incidentally encountered cue in the present experiments, is an example of the way in which a hint to the solution of a problem, encountered by chance during an incubation period, might impart extra activation to the solution, making it more accessible, causing an incubation effect.

### ***Incidental Clues***

Pasteur's notion that "chance favors the prepared mind" implies that when random hints come along, one must be ready to use such clues to solve problems, a theory sometimes known as *opportunistic assimilation* (e.g., Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995). Whether chance hints automatically aid the resolution of unsolved problems is the issue under consideration in the present study. Do hints in the environment, such as a fourth word associated with the solution to a RAT triad (Figure 1), unconsciously prime solutions to problems? Beyond the question of whether sub-threshold activation is imparted to problem solutions during initial problem attempts, there is the question of whether encounters with stimuli during an incubation period (i.e., the time when conscious work on a problem has been suspended) impart additional activation to solutions, making them more accessible when problems are retested.

Findings that hints given during an incubation interval facilitate performance on a retest have been fairly common (e.g., Brown & Cruse, 1988; Dominowski & Jenrick, 1972; Dorfman, 1990; Driestadt, 1969; Mednick, Mednick, & Mednick, 1964; Moss, Kotovsky, & Cagan, 2007, 2011). Furthermore, there is some reason to believe that hints in the environment might contribute unconsciously to the discovery of insightful solutions to

problems. For example, participants working on the classic two-string problem, typically used to demonstrate functional fixity (Maier, 1931), have difficulty in thinking of using a pendulum to solve the problem. Maier found, however, that when a seemingly accidental hint was given in which the experimenter brushed one string, setting it swinging, subjects often used the hint to quickly solve the problem, even though they seemed unaware of having used the hint to reach a solution. In another example, Moss et al. (2007) referred to their own incidentally presented cues as “implicit hints,” and claimed that most of their experimental participants were not aware they had seen the hints.

Other research, however, suggests that hints may not automatically yield solutions, but rather that hints must be deliberately considered within the context of the problem. Studies of analogical transfer in problem solving show that hints to the solutions of problems in the form of story analogues rarely stimulate spontaneous transfer, although subjects are able to use the analogues when instructed to do so (e.g., Gick & Holyoak, 1980, 1983). Context-dependent transfer of analogues was found by Spencer and Weisberg (1986), who found that when the context was changed from the time when the base analogue was presented to the time when the target problem was given, no transfer occurred unless subjects were explicitly informed about the relation between the base analogue and the target problem. It may be that opportunistic assimilation only succeeds if hints are intentionally applied to the problem. This line of reasoning leads to the hypothesis that the way that hints facilitate problem solving is not by providing passive spreading activation in a way that increases the accessibility of solutions.

A set of experiments similar to the present ones was reported by Dodds et al. (2002). In that study participants had two attempts at solving the same set of RAT problems, the two attempts separated by an intervening (incubation) period, during which hints were sometimes inserted. The hints were of two different types; some were solutions to the RAT problems, and some were semantic associates of solution words. The critical incubation task in which hints were inserted among other irrelevant words was called a “make-a-word” task, in which participants tried to make three words from the letters of each of 20 stimulus words. This task, which, along with an unrelated insight problem, took about 15 minutes, whereupon participants were retested on the RAT problems. Dodds et al. found that semantic associates did not increase resolution of initially unsolved RAT problems; if anything, they impaired resolution, relative to a control condition. Solution words given as hints in the intervening task did benefit resolution, but only when participants were instructed to be alert to hints that might help on the upcoming retest of the RAT problems (before the incubation tasks were given, all participants were forewarned that there would be a final retest of RAT problems). Moss et al. (2007), who found benefits of priming RAT solutions in incidental tasks without instructing participants to be alert for hints, suggested that the “make-a-word” incubation task used by Dodds et al. “involved mainly orthographic processing and not semantic processing,” pointing out that semantic tasks

yield more robust priming effects. Using a lexical decision task to prime RAT solutions, Moss et al. (2007, 2011) found benefits in terms of resolution of RAT problems without instructing participants to monitor the lexical decision stimuli to find hints to the solutions of RAT problems.

Given that Dodds et al. (2002) failed to find a benefit of semantically related hints on problem resolution, it is difficult to interpret this noneffect, because Dodds et al. also failed to find a benefit of solution priming when participants were not alerted to watch for hints. Moss et al. (2007, 2011) have since demonstrated repeated findings of solution priming without such alerting instructions when a task requiring greater semantic processing (i.e., a lexical decision task) was employed to prime solutions. There may have been impediments (e.g., too little semantic processing of priming stimuli) to solution priming in Dodds et al.'s methods that also prevented priming effects of semantically related hints in that study. Would greater semantic processing of semantically related hints reveal benefits of those related hints, a spreading activation effect?

### ***The Present Experiments***

In the present experiments, we tested the spreading activation theory of incubation in RAT problem solving, using methods similar to those of Dodds et al. (2002) and Moss et al. (2007, 2011). As in the Dodds et al. study, we tested effects of solutions as hints and related words as hints to see the effects of such stimuli on the resolution of initially unsolved RAT problems. Rather than the orthographic processing priming task used by Dodds et al., however, we used a lexical decision task to present hints incidentally, as was done by Moss et al. (2007, 2011). There were other differences between the Dodds et al. methods and the present methods designed to maximize the likelihood that priming effects would be seen in our experiments. The Dodds et al. study primed all items in a continuous block before RAT problems were retested, which meant a delay of more than 10 minutes between priming a hint and retesting its corresponding RAT problem; priming effects may have weakened during that time. In the present study, each RAT problem was separated from the next by 4 lexical decision items, the last of which (the hint) was seen a mere 3 seconds before its corresponding retested RAT problem. Finally, we also used reaction times in a lexical decision task, a direct test of spreading activation, to see if our semantically related hints truly primed RAT solution words in lexical decision (Experiment 3).

Experiment 1 confirmed that initially unsolved RAT problems are more likely to be resolved if the retest is preceded 3 seconds earlier by the actual solution word, encountered as a stimulus in an incidental lexical decision task. Using the same method, Experiment 2 tested whether semantically related words, rather than solution words, would also enhance problem solving resolution if the semantic associates were presented 3 seconds before problems were retested. In Experiment 3 the semantic associates to RAT solution words were tested to determine whether the associates primed the solution words in a lexical



decision task. This experiment was necessary to determine whether semantic activation spreads from the associates we used to their corresponding solution words.

In Experiments 1, 2, and 4, RAT problems were presented twice, the problems intermixed with trials of a lexical decision task. Immediately prior to the second presentation of a RAT problem was a word on the lexical decision task we will refer to as a cue word. In Experiment 1 the cue word was either an unrelated word or the solution to the subsequent problem. In Experiments 2 and 4 the cue word was either unrelated to the solution or a strong semantic associate of the solution word. The spreading activation theory predicted that more initially unsolved problems would be resolved at retest when the cue word was semantically related, rather than unrelated to the solution. One condition of Experiment 4 also involved instructing participants to intentionally use the cue words as hints for subsequent RAT problems. Related cue words were predicted only by the intentional version of the opportunistic assimilation theory to facilitate resolution of initially unsolved problems when the cues were intentionally used to aid problem solving.

## Experiment 1

In Experiment 1 participants were given two opportunities to solve each of 12 RAT problems. The two attempts at a problem were separated by a few minutes of work on other problems. Participants saw, immediately prior to the second presentation of each RAT problem, a cue word that was either the solution word or a word unrelated to the solution of the subsequent RAT problem. For example, prior to the second presentation of the RAT problem APPLE - HOUSE - FAMILY appeared either the solution word (e.g., *tree*) or a word unrelated to the solution (e.g., *ironic*). It was predicted that the probability that an initially unsolved problem would be resolved on a second attempt would be greater if the retest of a problem were preceded by a solution word. In question was whether an incidental cuing effect would be seen in an experimental paradigm using simple word problems. The incidental priming task required participants merely to decide whether or not the letter string formed a word.

## Method

### Participants

The 36 participants in Experiment 1 received partial credit towards the completion of their introductory psychology course. All participants in all of the reported experiments volunteered to participate in these studies, and writing options were available in their classes for class credit in lieu of experimental participation. Each experimental session included approximately 10 participants.



### Materials

The 12 RAT problems used and their corresponding cue words are listed in Appendix A. There were also 90 filler items, half of which were English words that were not obviously related to any of the RAT problem solutions (e.g., *ironic*), and half of which were nonwords that resembled words (e.g., *pormoil*). The stimuli were shown in uppercase black letters on a white background on a television monitor. Response forms had the words yes and no on each line corresponding to a trial of the lexical decision task, and a blank line corresponding to the presentation of each RAT problem.

The stimulus sequence (see Figure 2) presented 24 blocks of items, with each block consisting of four lexical decision items, followed by a single RAT problem. Thus, the procedure consisted of 120 trials, including 96 lexical decision trials, and 24 RAT problems (each of the 12 problems was repeated). The 12 RAT problems presented in the first 12 blocks were repeated in the same order in the next 12 blocks of trials. A nonword (in the lexical decision task) immediately preceded the first presentation of each RAT problem. A single word (in the lexical decision task), to be referred to as a cue word, appeared in the stimulus sequence immediately before the second presentation of each RAT problem. For six of the retested RAT problems, the immediately preceding cue word was the solution word, whereas the other six retested problems were preceded by unrelated words. Six of the 12 solution words were used to cue second presentations of corresponding RAT problems in counterbalancing A, and the other six were used in counterbalancing B.

### Procedure

The instructions informed participants that they would alternate between two different tasks: a lexical decision task, and a Remote Associates Test. For each trial of the lexical decision task a letter string appeared on a television screen for 2 seconds. Participants then had 3 seconds to circle either yes (if the letter string formed an English word) or no (to indicate the string was not a word) in the appropriate spaces on their response forms. For each RAT problem participants were given 10 seconds to write the solution. A solution was described as a single word that formed a common two-word phrase or compound word with each of the three RAT problem words. The example that was given was the problem CHECK-MARK-NOTE, for which the solution is the word *book* (CHECK-*book*, *book*-MARK, and NOTE-*book*). The instructions stated that RAT problems would be repeated at times, and that participants should never go backwards on their response form to fill in a solution once the 10 seconds for the problem had elapsed. After the instructions had been explained, the 120 trials of lexical decision items and RAT problems were shown.

### Design

Priming (solution word vs. unrelated word) was a within-subjects factor, and counterbalancing (A vs. B) was manipulated between-subjects. Each participant's resolution score was calculated as the number of initially unsolved problems that were solved at retest

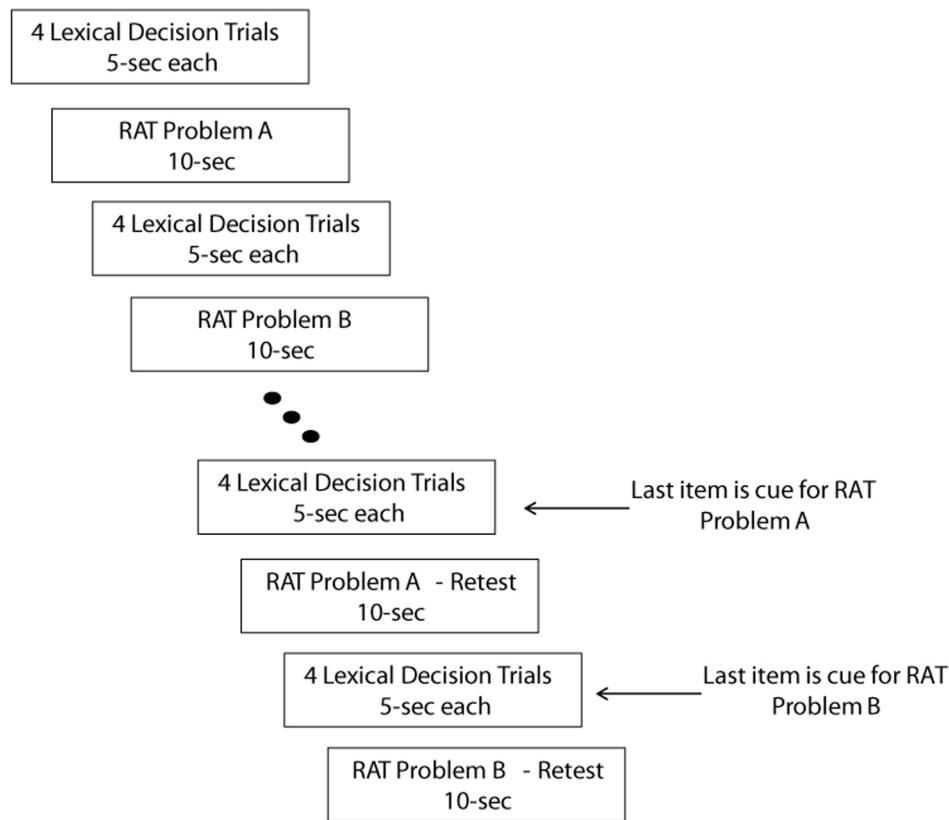


Figure 2. Sequence of trials are shown for Experiment 1. Lexical decision trials during which the last word presented acts as a cue for the subsequent retested RAT problem are labeled.

divided by the number of initially unsolved problems. Resolution scores were computed separately for retested problems corresponding to solution word cues vs. retested problems corresponding to unrelated cues.

### Results and Discussion

The RAT problems were solved on their first presentation 51% of the time, leaving approximately half of the problems initially unsolved. The resolution rate was computed as the proportion of initially unsolved problems that were successfully solved at retest. A one-way within-subjects ANOVA was computed to analyze the effect of cuing, using the proportion of resolved RAT problems as a dependent measure. Cuing, a repeated factor, was either related (i.e., the solution word was primed) or unrelated. Counterbalancing, a between-subjects factor, had no significant effect, and therefore was not included in the analysis. There was a significant effect of cuing,  $F(1,35)=23.06$ ,  $p<.0001$ ,  $MSE=.035$ , the resolution rate for retested problems was approximately four times as great when problems were primed with solutions than when they were primed with unrelated words.

The finding that initially unsolved problems are better resolved when the actual solutions are seen before the retest is hardly surprising. Importantly, this result shows that within the experimental paradigm used in the present experiments, the primed word was highly effective in aiding resolution rates. That is, when primed solution words were presented in an incidental task, and preceded retested RAT problems by only 3 seconds, there was a clear benefit to solving the problems. This result is important for interpreting the effectiveness of semantically related primes on resolution rates (Experiments 2 and 3), because it shows that problem solving in our experimental paradigm is sensitive to such priming effects.

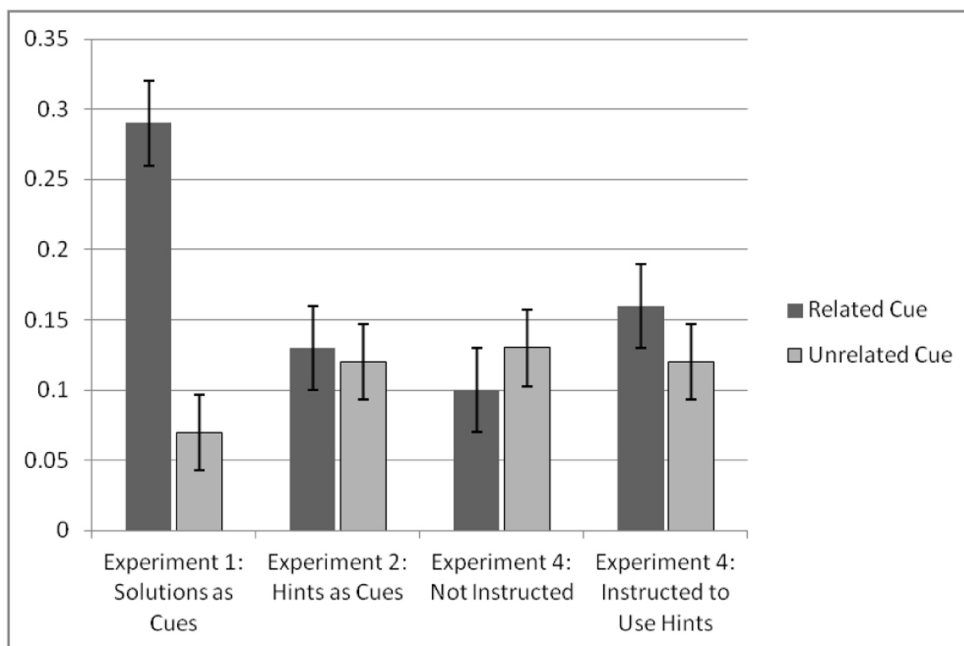


Figure 3. Resolution rates are shown as a function of cuing in Experiments 1, 2, and 4. Related cues were solution words in Experiment 1, and semantic associates of solution words in Experiments 2 and 4. In Experiment 4, participants were instructed vs. not instructed to look for RAT clues in the interleaved lexical decision task. Error bars show standard errors of the mean.

## Experiment 2

Given that actual solution words facilitated resolution of initially unsolved RAT problems, is it the case that semantic associates also facilitate the resolution of initially unsolved RAT problems? In Experiment 2, as in Experiment 1, participants had two chances to solve the RAT problems. Just 3 seconds before the second presentation of each RAT problem, a cue word was shown that was either unrelated or semantically related to the solution of the subsequent RAT problem. For example, prior to the second presentation of the RAT

problem APPLE - HOUSE - FAMILY appeared either the related cue word (e.g., *leaves*) or an unrelated cue word (e.g., *ironic*). The passive spreading activation hypothesis predicted that the probability that an initially unsolved problem would be resolved on a second attempt would be greater if the retest of a problem were preceded by a word that was semantically related to the solution word.

### **Method**

#### **Participants**

There were 64 participants whose only task was to provide associates for RAT solution words. An additional 55 participants were randomly assigned to counterbalancing groups for blocks of RAT problem solving, lexical decision trials, and second attempts at RAT problem solving. Each session included 5-12 participants.

#### **Materials, Design & Procedure**

The materials, design, and procedure for Experiment 2 were exactly the same as for Experiment 1, except that the cue words used were not the actual solution words, but rather semantic associates of the solution words. The materials, including the semantic associates used, are shown in Appendix A. In order to generate a set of associates to the RAT solution words, the 12 solution words for the 12 problems were given as free association stimuli to participants, who were asked to list any words they could think of that would form compound words or two-word phrases with the solution words. The task was self-paced. The resulting set of associates was used to select a semantically related associate corresponding to each solution word. The most common associate for each solution word was selected, except that associates were rejected if they were problem words (e.g., the RAT problem word "white" as an associate of "snow"), or if they did not unambiguously relate semantically to solution words (e.g., "big" as an associate for "dog"). The average forward association strength, that is, from the selected set of associates to the corresponding solutions, was .18, according to the association norms by Nelson, McEvoy & Schreiber (1998)<sup>1</sup>.

### **Results and Discussion**

Problems were solved on their first presentation 33% of the time, leaving approximately two-thirds of the problems initially unsolved. The resolution rate was computed as the proportion of initially unsolved problems that were successfully solved at retest. A one-way within-subjects ANOVA was computed to analyze the effect of cuing, using the proportion of resolved RAT problems as a dependent measure. Cuing, a repeated factor, was

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<sup>1</sup>This average association strength does not include the association strength between the associate "leash" and the solution word "DOG," because "leash" was not included as a cue word in Nelson et al.'s (1998) association norms.

either related or unrelated. Counterbalancing, a between-subjects factor, did not have an effect, and therefore was left out of subsequent analyses. There was no main effect of cuing,  $F(1,53) = .27$ ,  $MSE = .010$ . The mean resolution rates for related versus unrelated cuing conditions are shown in Figure 3.

It also seemed possible that participants might occasionally write down cue words, rather than correct answers, as solutions to RAT problems. Across all participants and all RAT problems there were numerous incorrect answers that were written as solutions. Nonetheless, there was only one case in which a participant wrote a cue word as a solution. Thus, the lack of a cuing effect does not appear to have been caused by participants believing that cue words were actually correct solutions.

The results show that cuing retested RAT problems with semantically related words did not facilitate resolution of the initially unsolved RAT problems. Why not? One possibility may be that priming may be weaker when primed stimuli are not processed semantically (e.g., Becker, Moscovitch, Behrman & Joordens, 1997); it is not clear what degree of semantic processing was engendered by the lexical decision task used as an incidental task in the present experiments. However, a lexical decision task was sufficient to produce priming effects in Moss et al.'s (2007, 2011) experiments when actual solutions were used as cue words, as well as in Experiment 1 of the present study, so it is unclear why semantic associates would not have similar priming effects given that the procedure of Experiment 2 was the same as that of Experiment 1. Therefore, the failure of the semantically related words to cue RAT solutions in Experiment 2 can be taken as evidence that passive spreading activation from semantically related words does not facilitate resolution of initially unsolved problems.

### Experiment 3

The fact that incidentally presented semantic associates of solutions did not aid problem solving might mean that the associates we used in Experiment 2 do not truly cause activation to spread to solution words. The classic method for demonstrating spreading activation has been the lexical decision task (e.g., Meyer & Schvaneveldt, 1971). Do the associates used in Experiment 2 truly prime the solution words in a lexical decision task? The goal of Experiment 3 was to test associates of solutions to RAT problems for their ability to prime the solution words. The semantic associates to solution words were those originally generated in the free association task in Experiment 2. Experiment 3 tested whether passive spreading activation from associates would spread to solution words, as measured by a lexical decision task. It was predicted that decision times for solution words would be faster when those words were immediately preceded by related associates than when the immediately preceding primes were semantically unrelated to solutions.

## ***Method***

### **Participants**

There were 46 participants who participated in the lexical decision task.

### **Materials**

There were 72 verbal stimuli presented in a session, 36 of which were words, and 36 of which were nonwords that resembled English words (e.g., “pormoil”). The 36 words shown in each of the two counterbalancings were drawn from a set of 42 words, 12 of which were the RAT solution words, 12 of which were associates related to the solution words, and 18 of which were words unrelated to solutions and associates. Each counterbalancing included all 36 nonwords, all 12 solution words, all 18 filler words, and six of the 12 associates of solution words. The six associates used in counterbalancing A were different from the six used in counterbalancing B.

### **Procedure**

Micro Experimental Laboratory (MEL) software was used. Participants sat facing a computer screen with the left index finger resting on the “1” key and the right index finger on the “0” key. Instructions to participants, which were shown on the computer screen, indicated that the “0” key was to be pressed when a nonword was shown, and the “1” key was to be pressed when a word appeared. Participants were urged to press the correct key for each item as quickly as they could give an accurate response. There were 3 seconds given between each response and the onset of the next verbal stimulus.

### **Design**

Half of the 12 solution words in each of the two counterbalancings were immediately preceded by related associates (the primed items), and half were preceded by unrelated words (the nonprimed items). The six items that were primed in counterbalancing A were nonprimed items in counterbalancing B, and vice versa. Thus, priming (primed vs. nonprimed) was manipulated within-subjects, and counterbalancing (A vs. B) was manipulated between-subjects.

## ***Results and Discussion***

A one-way ANOVA compared the reaction times for primed vs. nonprimed responses to solution words, a within-subjects comparison. The effect of priming was significant,  $F(1,45) = 32.37$ ,  $MSE = 1325.30$ , responses to solution words were faster when the words had been preceded by related words ( $M = 583$  msec) rather than unrelated words ( $M = 626$  msec), a mean difference of 43 msec. The priming effects for all but two of the items exceeded 30-msec.

The selected associates successfully primed the semantically related RAT solution words. This result clearly satisfies the standard criterion, showing that activation reliably

spreads from the associates to the RAT solutions (e.g., Meyer & Schvaneveldt, 1971). It is also noteworthy that priming did not depend on any intentional relation of primes to RAT solution words; participants were not instructed or encouraged to relate test stimuli in any way. Therefore, it can be concluded that activation appears to have passively spread from associates to RAT solution words in Experiment 3.

## Experiment 4

There were two purposes for conducting Experiment 4. One purpose was to replicate the noneffect of cuing on the resolution of initially unsolved RAT problems, using a larger number of participants in order to enhance the power for detecting effects. The second purpose was to determine whether the cue words could be intentionally used as hints to facilitate resolution. Even if the results do not support a passive spreading activation theory of incubation effects, it may be possible nonetheless that hints encountered in the environment can be intentionally used to facilitate resolution of initially unsolved problems.

### **Method**

#### **Participants**

There were 152 participants in Experiment 4; 79 participants were in the nonintentional instruction condition, and 73 were in the intentional instruction condition.

#### **Materials**

The same materials described for Experiment 2 were used in Experiment 4.

#### **Procedure**

The procedure in Experiment 4 was the same as that used in Experiment 2, with one exception. In the intentional instruction condition participants were told that sometimes the words immediately preceding RAT problems could provide hints to the subsequent problem solutions. The intentional instructions stated, "Some of the Remote Associates Test problems will be preceded by hints. That is, for some, but not all problems, the word that appears just before the problem on the word decision task will be closely related to the solution to the problem. Pay attention to those words, and try to use the hints to help you solve the problems." This instruction was omitted in the nonintentional instruction condition. As in Experiment 2, half of the retested problems were immediately preceded by cue words, and half were preceded by unrelated words.

#### **Design**

Cuing, a within-subjects variable, was either related or unrelated cues. Counterbalancing (A vs. B) and instruction (intentional vs. nonintentional) were between-subjects variables.



### **Results and Discussion**

The solution rate for initial attempts at RAT problems was 36%. A 2 (cuing) X 2 (instruction) ANOVA was computed, using resolution rate as the dependent measure. Cuing, a within-subjects factor, was either related or unrelated cues. Instruction, a between-subjects factor, was either intentional or nonintentional instructions. There were no significant main effects of instruction,  $F(1,150) = 1.02$ ,  $MSE = .03$ , or of cuing,  $F(1,150) = .04$ ,  $MSE = .010$ . There was a significant cuing X instruction interaction,  $F(1,150) = 7.51$ ,  $MSE = .010$ , related cues, relative to unrelated cues, improved resolution in the intentional instruction condition, but impeded resolution in the nonintentional instruction condition. The means for these conditions are shown in Figure 3. Simple main effects analyses indicate that cuing with related items marginally reduced resolution rates in the nonintentional instruction condition,  $F(1,79) = 3.72$ ,  $p = .057$ ,  $MSE = .010$ , but improved resolution in the intentional instruction condition,  $F(1,73) = 3.76$ ,  $MSE = .010$ .

The same analysis was repeated, using only those ten items that showed substantial priming effects in Experiment 3<sup>2</sup>. The main effects were not significant (both  $F$ 's < 1.0). There was a significant cuing X instruction interaction,  $F(1,150) = 7.77$ ,  $MSE = .011$ , as in the previous analysis; related cues, relative to unrelated cues, improved resolution in the intentional instruction condition (mean for related cues/intentional = .16, mean for unrelated cues/intentional = .12), but impeded resolution in the nonintentional instruction condition (mean for related cues/nonintentional = .11, mean for unrelated cues/nonintentional = .14). The simple main effect of related cues in the intentional instruction condition was significant,  $F(1,72) = 5.85$ ,  $MSE = .018$ , but the simple main effect of cuing in the unintentional instruction condition was not significant,  $F(1,78) = 2.30$ ,  $p = .13$ ,  $MSE = .012$ . The latter result indicates that related cues in the nonintentional condition did not reliably impede resolution.

The results of Experiment 4 replicate and extend those of Experiment 2. Most importantly for the passive spreading activation theory, it was once again clear that when participants were not instructed to use the cue words intentionally as hints, the presence of semantically related cues before the retest did not aid resolution of initially unsolved RAT problems. In fact, surprisingly, the related cues appeared to have slightly impeded resolution, although this marginal effect was not significant when analyses were restricted to only those ten items that showed positive priming effects in the lexical decision task in Experiment 3. It is not clear what may account for this apparent trend. It may be, for example, that incidentally presented cues may have interfered with the retrieval of correct solutions, as was reported by Smith and Blankenship (1991). This possibility seems

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<sup>2</sup>Two semantically related hints, "run" (hint for solution word "WALK" for RAT problem "BOARD-CAT-SLEEP") and "sticky" (hint for solution word "TAPE" for RAT problem "RECORDER-DECK-SCOTCH") had mean priming effects that were negative; these items were eliminated from this analysis, and the remaining 10 items, whose mean priming effects were positive, were used in this analysis.

weak, however in that the effect was not significant, nor was it even marginal when only the strongest cues were used in the analysis, and the effect was not found in the same condition of Experiment 2. In contrast to these results, the intentional use of semantically related hints facilitated resolution of initially unsolved RAT problems. Unless the semantic associates were intentionally applied to the problems, however, they did not produce a facilitative effect on resolution through some passive process, such as spreading activation.

## General Discussion

The findings of the four experiments reported here are inconsistent with predictions of a passive spreading activation theory of incubation effects. This theory states that solutions are activated below a conscious threshold during initial attempts that fail to solve a problem. Additional activation spreads to the partially activated solutions from chance encounters with semantically related stimuli, enabling those solutions to be generated. Experiment 1 demonstrated a priming effect; when the actual solution was read 3 seconds before the corresponding RAT problem was retested, resolution scores significantly increased. In Experiment 2, however, resolution scores did not benefit when close associates to the solutions were read a mere 3 seconds before corresponding problems were retested, using the same procedure as in Experiment 1. In Experiment 3, when, in a lexical decision task, semantic associates were seen 3 seconds before solution words, there was a significant priming effect, showing the traditional spreading activation effect for the same materials we used in the RAT problem solving tasks. Finally, Experiment 4 showed that when semantic associates that served as cue words before RAT problems were retested, resolution was again unimproved when the associates were seen as incidental to the problems; however, resolution was significantly improved if participants were advised to intentionally use the semantic associates as hints.

Semantically related cue words helped participants retrieve RAT solutions only when participants were explicitly instructed to use cue words as hints for the RAT problems (Experiment 4). The facilitative effect of intentionally using cue words as hints for the RAT problems shows that the cue words, in and of themselves, did not impede retrieval of correct solutions. This result is consistent with findings that analogues do not spontaneously transfer to newly encountered problems, but rather that attention must be directed to relate the base analogue to the target (e.g., Gick & Holyoak, 1980; 1983). The general pattern that emerges from these studies is that an active use of incidentally encountered information is necessary if one is to take advantage of hints that might facilitate resolution of unsolved problems.

There is a body of research, however, that indicates that knowledge is sometimes recruited for problem solving even in the absence of instructions to use that knowledge intentionally. Under transfer-appropriate conditions (e.g., Morris, Bransford & Franks,

1977), analogues or primed knowledge may transfer to new problem solving situations (e.g., Needham & Begg, 1991; Schunn & Dunbar, 1993). Word fragment completion, a very simple problem, is also sensitive to transfer-appropriate processing (e.g., Blaxton, 1989; Roediger & Blaxton, 1987). In these situations solutions to problems are primed, and the solutions are used without any obvious deliberate attempts by problem solvers to retrieve the material. Although implicit priming in simple problem solving appears to occur, it is noteworthy, nonetheless, that none of these implicit problem solving situations involve spreading activation from semantic associates. Rather, the implicit memory studies show repetition priming of solutions, but not semantic activation spreading to solutions.

Our two failures to find facilitative effects of semantic associates on RAT problem solving might have been the result of Type II errors, but several facts argue against this possibility. First, in Experiment 4, those not instructed to use the hints showed (numerically) worse problem resolution when problems were primed with semantic associates. This trend toward a blocking (rather than a facilitating) effect suggests that more power would not have shown a significant advantage of semantically related cues. Second, our experimental procedure was adequate for producing a facilitative priming effect in Experiment 1, and again in Experiment 4, when participants were instructed to use hints; therefore, it should have been adequate for producing priming effects with semantic associates. Furthermore, to make claims concerning effects or noneffects of spreading activation on the resolution of initially unsolved problems, it was necessary to demonstrate that the RAT solution words were primed in a lexical decision task by our selected associates. Such a priming effect is a standard criterion used in operational definitions of spreading activation. Experiment 3 showed that the selected semantic associates primed solution words on a lexical decision task, indicating that associates impart spreading semantic activation to solution words. Given that the procedure produced positive priming effects with solutions as hints, and that our associates produced a significant priming effect in lexical decision, it can be concluded that if there is a spreading activation effect on RAT problem solving, it is a very small effect. It may be that our semantic associates produce such little activation that many such clues would be needed to produce a facilitative priming effect.

Although the results of the present experiments are inconsistent with a passive spreading activation theory of incubation, they do not necessarily contradict the assertion of Yaniv and Meyer's (1987) memory sensitization hypothesis that activation from an initial attempt at a problem accrues and persists at nodes representing information that may be critical for solving problems. Such activation and persistence of activation was not tested in the present experiments. The results do imply, however, that if memory sensitization is important for incubation, then it is not because chance encounters with relevant stimuli passively bestow the extra activation needed to bring solutions or key information above the threshold of conscious awareness. The present results also do not constitute a critical test of Bowers et al.'s (1990) theory of intuitive guiding, which, like the

memory sensitization hypothesis, is based on the mechanism of unconscious activation. The existence of unconscious activation, and even its putative role in intuitive guiding or the sensitization of unsolved problems has not been tested in the present experiments. What is inconsistent with the results of the present study, however, is the prediction that semantic activation that passively spreads to solutions from incidental encounters with stimuli causes incubation effects in problem solving. In the present study, passive spreading activation was not a sufficient condition to aid the resolution of initially unsolved problems.

The present results challenge, to some degree, the notion that unconscious cognitive mechanisms autonomously and incrementally construct solutions to insight problems. The very label incubation implies an unseen incremental process of development, and applied as an analogy to creative cognition, the label implies an unconscious work theory of incubation effects, that is, a theory that attributes sudden insight experiences to incremental unconscious mechanisms (e.g., Weisberg, 1993). Spreading activation, a theoretical process, constitutes an unconscious cognitive mechanism that could cause incubation effects. The present experiments should encourage skeptics of such unseen mechanisms in creative cognition.

#### Appendix A: RAT Problems with Corresponding Solution and Cue Words

<b>Problem</b>	<b>Solution</b>	<b>Associate</b>
STORM-BALL-WHITE	SNOW	flake
COAL-ARM-STOP	PIT	barbeque
SKATE-WATER-CUBE	ICE	freeze
DUSTER-BED-WEIGHT	FEATHER	pillow
HEAD-GOOSE-SALAD	EGG	scramble
CATCHER-LICENSE-HOT	DOG	leash
HIGH-EASY-ELECTRIC	CHAIR	sit
SHOE-CAR-TOP	BOX	square
BOARD-CAT-SLEEP	WALK	run
FAMILY-APPLE-HOUSE	TREE	leaves
RECORDER-DECK-SCOTCH	TAPE	sticky
SUIT-SHIP-PARKING	SPACE	stars

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